3 MANURE PRODUCTION AND MANAGEMENT

3.1 Manure Quantities Among Animal Populations

Animal farms produce as much manure as small and medium-size cities. A farm with 2500 dairy cattle is similar in waste load to a city of 411,000 people. Since about 1970, production of hogs, beef, poultry, and dairy has become concentrated into fewer large units. Between 1982 and 1997, the most recent years for which animal census data are available, the number of livestock has remained relatively constant, but the number of farms has declined significantly. Dramatic changes have occurred in American agriculture between 1982 and 1997, the most recent years for which animal census figures are available. The most significant change is the shift from small farms to the much larger, concentrated animal feeding operations (CAFOs). Table 3.1 shows a summary of changes in confined animal units from 1982 to 1997.

Table 3.1 Change in confined animal units, 1982 to 1997

Animal type	Size class	1982	1997	Percent change
Milk Cows	300-999	1,281,300	1,835,832	+43
	>1000	578,223	2,135,205	+265
	All smaller size classes decreased			
Beef	150-299	647,880	721,624	+11
	300-999	615,890	836,548	+36
	>1000	325,150	508,268	+56
	All smaller classes decreased			
Swine	150-299	948,702	1,196,911	+26
	300-999	654,301	2,113,110	+223
	>1000	213,048	2,851,534	+1238
	All smaller classes decreased			
Poultry	150-299	651,816	1,264,537	+94
	300-999	881,644	1,650,785	+87
	>1000	835,889	1,832,509	+119
	All smaller classes decreased			

The definition of a CAFO listed in the regulation development document (USEPA, 2001) is used in this document. A CAFO is an animal feeding facility that has more than 1000 animal units, or has between 300 and 1000 animal units and meets certain conditions or is designated a CAFO by the state, or has less than 300 animal units and is designated a CAFO by the state. The smaller size facilities are designated CAFOs primarily due to the potential the facility has for discharging pollutants to the waters of the United States. Animals must also be present in the facility for at least 45 days. The CAFO neither stores nor grows crops. Waste containment and disposal are also part of the CAFO designation. Poultry facilities are CAFOs if they contain more than 55,000 turkeys; 100,000 or more broilers or hens with continuous overflow watering; 30,000 or more hens or broilers with a liquid manure system; or 5,000 or more ducks. Designation as a CAFO requires the facility to obtain a NPDES discharge permit.

In 1982, CAFOs comprised only 3% of all farm operations and more importantly, only 35% of the total animal population. In 1997, CAFOs had risen to 5% of all farm operations and 50% of the animal population. The circumstances associated with these changes in animal population are unique for each of the four principal farm animal group categories; beef cattle, dairy cattle, hogs, and poultry. Table 3.2 shows the changes in CAFO operations from 1982 to 1997, based on animal unit size classes.

These changes have been principally driven by economic factors, mostly economy of scale, that is, a few large farm units have the potential to be much more cost and operationally efficient than many small farm units. Perhaps the significance of the reduction in small farm units maybe made most dramatically by comparing the numbers of farm units in 1982 to 1997. In 1982, there were 1,260,085 farms with fewer than 150 animals compared to 921,957 in 1997. This represents a 26% reduction in the total number of small farm units. Meanwhile, the number of large farms with more than 1000 head of livestock increased from 5442 farms in 1982 to 8021 farms in 1997, which represents a 47% increase. And of course, the actual "shift" in numbers of animal units is even more dramatic. There were 45.8 million animals on small farms in 1982, but by 1997 this number was reduced to 34 million animals. Interestingly, this is a 26% reduction in the total animal population for small farms. In contrast, large farm operations, that is, those with more than 1000 animals, increased from 15.7 million in 1982 to 24.9 million in 1997, a 58% increase.

Table 3.2 Change in CAFO operations from 1982 to 1997

Animal type	Size class[1]	1982	1997	Percent change
Milk cows	300-999	3,385	4,534	+34
	>1,000	456	1,303	+186
Other beef and dairy	150-299	34,370	36,421	+6
	300-999	16,827	19,541	+16
	>1,000	2524	3,008	+19
Swine	150-299	4,730	5,726	+21
	300-999	1,432	4,134	+189
	>1,000	103	1,011	+882
Poultry	150-299	3,175	6,129	+93
	300-999	1,786	3,312	+85
	>1,000	362	688	+90

[1]All smaller size classes decreased in number

Different parts of the United States are associated with major production facilities. See Figures 3.1 through 3.4 for locations of major animal production locales. The different animal production sectors are vertically integrated to various degrees. Poultry production is most highly integrated, followed by pork, dairy, and beef. The manure production by all of these animals is immense. Manure production varies by the animal species, diet of the animal, and age of the animal. Table 3.3 presents some data comparing manure production by the major animal groups.

Table 3.3 Manure production per 1000 pounds live weight, on an annual basis.

Animal Species	Manure produced lbs./yr	Typical Handling System	Tons per Year for 1000 Animal Unit CAFO
Swine	29,000	Liquid	14,500
Poultry			
Broilers	28,000	Solid	14.000
Layers	22,000	Liquid	11,000
Turkeys	16,000	Solid	8,000
Beef	21,000	Solid	10,500
Dairy	30,000	Liquid	15,000
Humans	1,223[1]	Liquid	611

[1] Based on 150 lb avg. wt. per person producing 0.5 lb of fecal material per day

On a 1000 pound live weight basis, each of these animals produces more waste than a human. A CAFO with 1000 animal units of turkeys produces a waste load comparable to a city of 87,700 people. A dairy CAFO with 1000 animal units is equivalent to a city of 164,500 people. The important difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated by virtue of the storage methods used before disposal.

3.1.1 Poultry

Poultry production (broilers, roasters, turkeys and eggs) is heavily concentrated in relatively few states. Chicken production occurs in Georgia, Arkansas, Alabama, Michigan, North Carolina, Missouri, Texas, and Delaware. Egg production occurs in Ohio, California, Pennsylvania, Indiana, Iowa, Georgia, Texas, Arkansas, and North Carolina. Turkey production occurs in North Carolina, Minnesota, Virginia, Arkansas, California, Missouri, and Texas. These states are those with the largest facilities. Other states may have CAFO sized production units, but not be among the largest. Poultry are not usually calculated as animal units due to the composition of their manure. Broiler manure has a N:P ratio of 3.6:1 and layer manure has a N:P ratio of 2.7:1. The N:P ratio of turkey manure is about 2.7:1. Poultry manure is quite high in phosphorus compared with other animal species. In some cases N and P are almost equal in concentration.

The total quantity of 120 million wet tons of poultry manure was estimated for 2001, and this figure represents an increase of more than 80 % compared to 1982. Clearly, this quantitative increase is the greatest change for all categories of animal fecal production. Some of the largest poultry operations are now located in North Carolina, Arkansas, and the Delmarva peninsula. Today, most poultry production comes from large concentrated egg or broiler operations. Delaware, as one example, may produce up to 250,000,000 chickens or more in one year. The waste generated contains more nitrogen and phosphorus than may possibly be used as fertilizer in Delaware for crop production.

Manure production and manure handling is similar in broilers and turkeys, resulting in similar nutrient concentrations. The floor is covered with moisture absorbing bedding and is ventilated. This airflow removes ammonia and other gases leaving a nitrogen-depleted manure. Broiler manure as excreted has a nitrogen content of 401 lb/yr/1,000 lbs of animal weight (USDA, 1998); broiler house litter has a nitrogen content of 27 lb/yr/1,000 lbs of animal weight (USDA, 1992). Some of this decrease in nitrogen may be explained by solubilization as when bedding is washed off the floor rather than scraped, as shown by the decrease in phosphorus and potassium from 117 and 157, respectively, to 113 and 111 lb/yr/1,000 lbs of animal weight. The much larger percent loss of nitrogen results from off-gassing of ammonia.

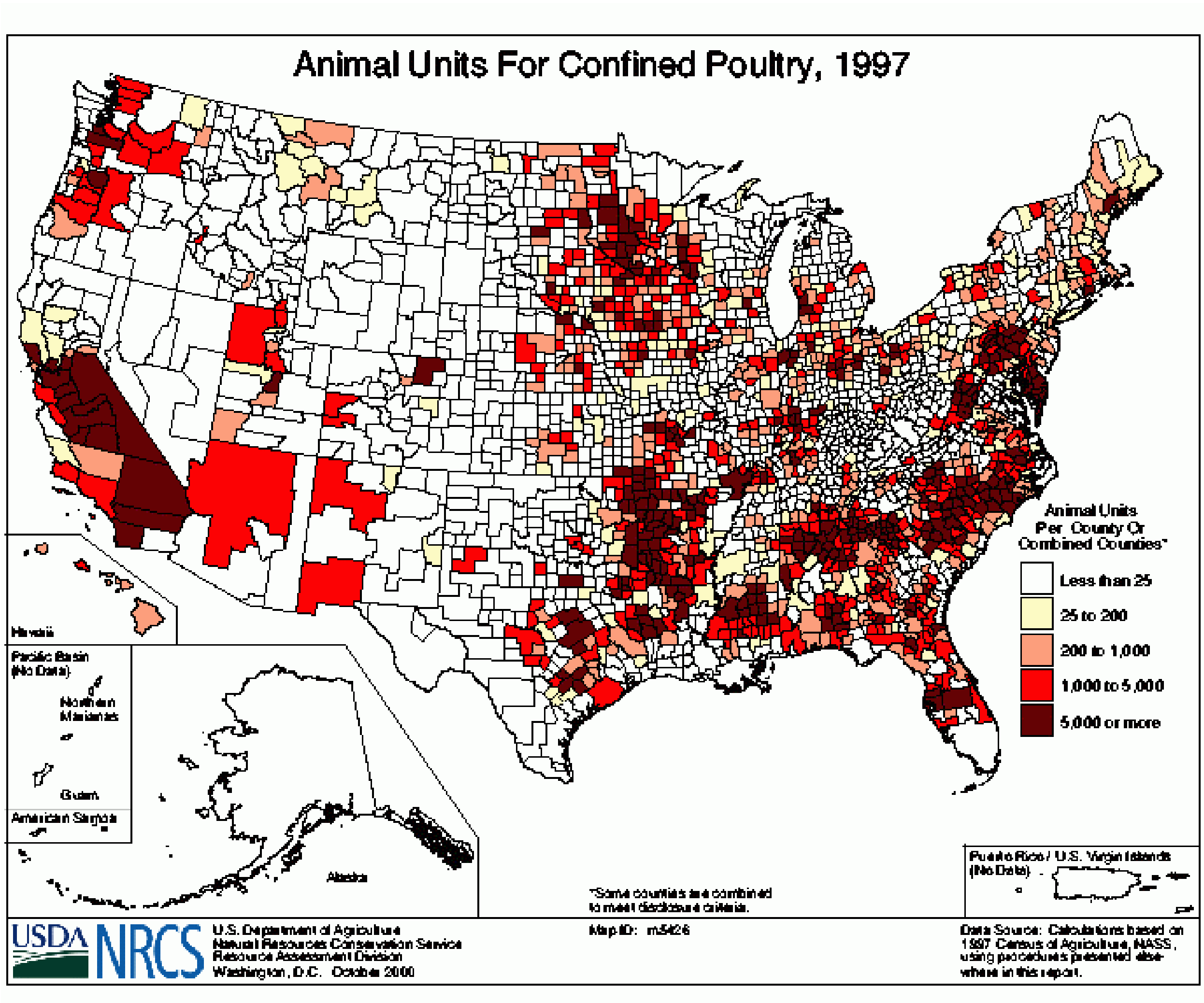

Figure 3.1. Poultry production distribution in the United States.

3.1.1.1 Broilers/Roasters and Turkeys

Broiler production in the United States was about 8.4 billion in 2001. The average cycle time for broilers is about 47 days. The total amount of waste generated by broilers is estimated at 79 million wet tons per year taking into account the cycle time of production. This estimate may be a high estimate because it does not take into account the fraction of birds sold at much lower weights for different markets. Turkey production also has multiple cycles per year. A good estimate is three production cycles of about 17 weeks each. The amount of waste generated is estimated at 21 million tons per year with three production cycles. Most waste is handled as dry rather than liquid systems.

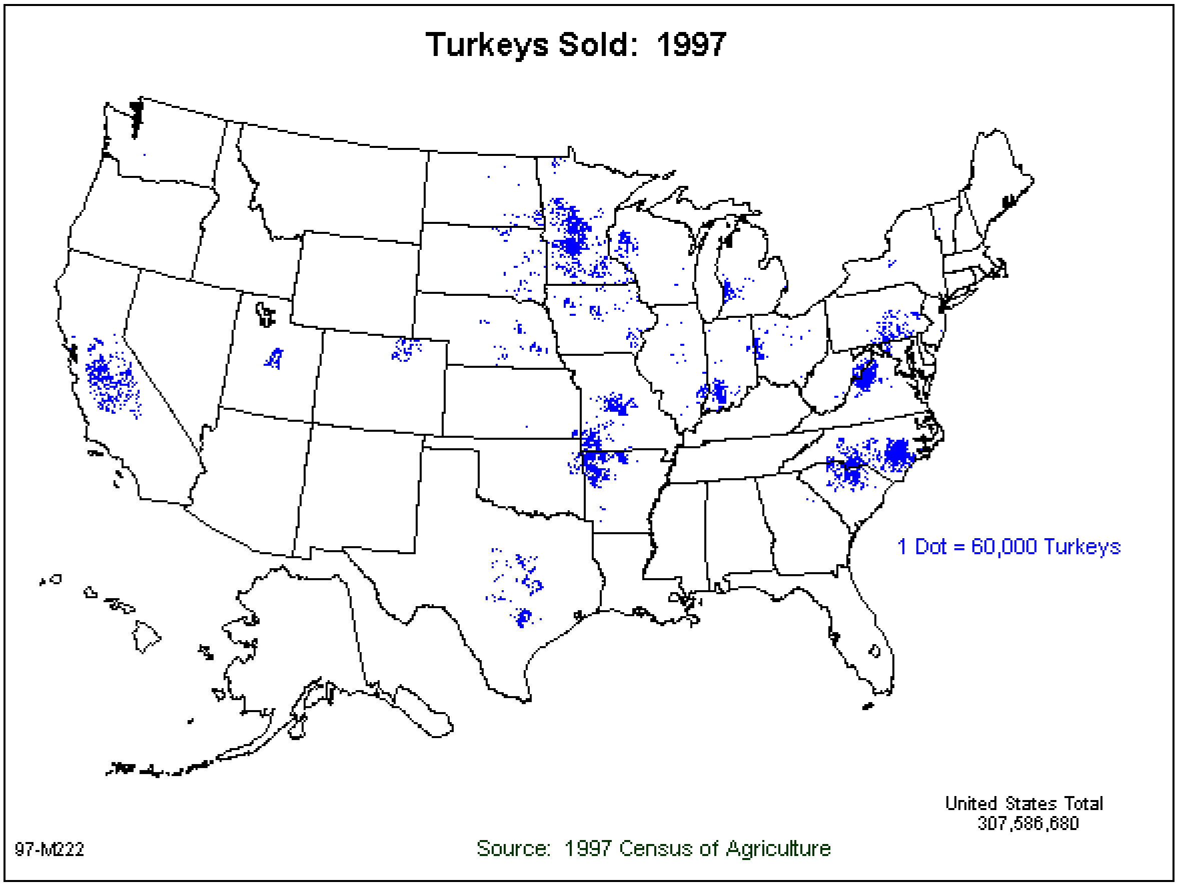

Figure 3.2. Turkey production distribution in the United States.

3.1.1.2 Layers

The estimated number of layers in the United States is about 367,000,000. The life cycle of layers is usually more than a year. The manure production by layers is estimated to be about 19 million tons per year. It is possible to have layer flocks more than one year in age before market. The apparent maximum for layers is about two years. Layer manure production often includes no bedding, it is handled as raw dried manure or water flushed manure. Water flushing manure results in dilution with concurrent increase in volume. Raw manure contains 308, 114, and 120 lb/yr/1,000 lbs of animal weight of nitrogen, phosphorus and potassium (USDA, 1998). Dry manure may lose up to 50% of the nitrogen content as volatile ammonia. Poultry manure dries rapidly and may be scraped off of flooring and stored dry in stacks or cakes. Dilution in lagoons and slurries may result in concentration reduction to as little as 10% of the raw manure value (USDA, 1992).

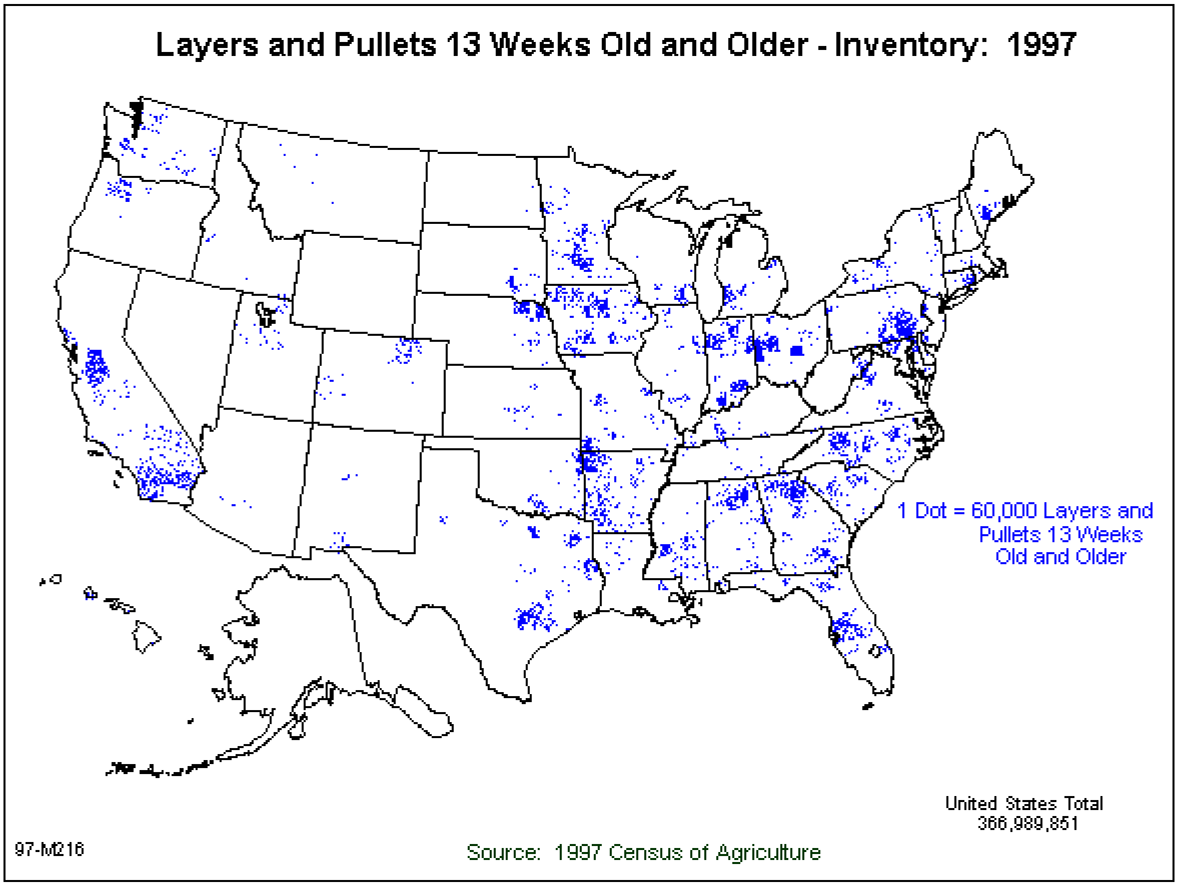

Figure 3.3. Layer and pullet distribution in the United States.

3.1.2 Swine

Hogs may live in several types of CAFOs throughout their life. Breeder facilities produce feeder pigs from birth to about 15 pounds, nursery facilities raise the pigs to 40 to 60 pounds, and grower/finisher facilities raise the pigs from 60 pounds to market weight of about 250 pounds. The total quantity of manure produced by both breeding hogs and hogs for slaughter was 177 million tons (from 8.5 million swine) and essentially this quantity was excreted in confined animal feeding operations. A variety of wet-handling and dry-handling systems were used. There has been a dramatic shift in the location of confined hog farm operations with North Carolina now being the most popular state with Iowa and Nebraska following behind. Figure 3.4 shows the change in confined animal units from 1982 to 1997. There has been a large shift to confined operations.

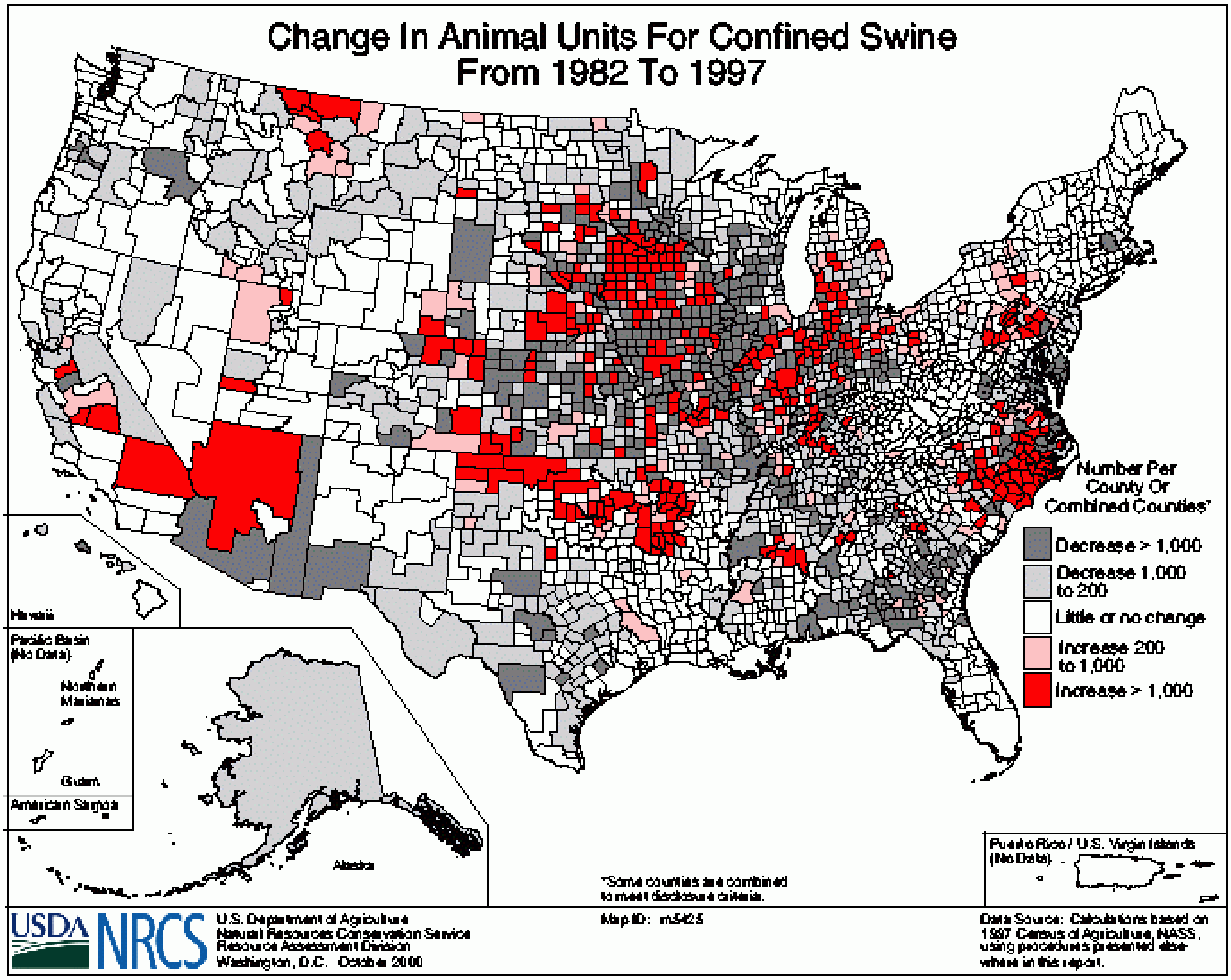

Figure 3.4. Change in swine production distribution in the United States.

Figure 3.5 shows a modern hog confinement facility with a waste lagoon. The hogs may be confined in pens as shown in Figure 3.6. In this type of facility the manure drops through the slatted floors into channels that are periodically flushed with supernatant water from the lagoon. The floors are either scraped or washed with water to move the waste into the subfloor channels. Demonstration projects have been completed wherein the lagoon is covered with a synthetic material, and the lagoon is converted to an anaerobic digester. Some farms have found it practical to recover methane from the lagoon to supply electricity and heat for the farm.

Photo courtesy of USDA NRCS.

Figure 3.5. Swine confinement barns with lagoon.

Photo courtesy of USDA NRCS.

Figure 3.6. Swine pens inside barn with slatted floors.

3.1.3 Cattle

3.1.3.1 Beef Feedlots

Beef cattle generate about 21,000 lbs of manure per animal per year, assuming one animal is one animal unit. Beef production starts with cow/calf operations that produce feeder calves for feeding operations. Calves are fed from birth to about 400 pounds. Then they are transferred to feeding operations that feed them to market weight of about 1200 pounds. Veal calves are usually male calves fed in confinement to about 450 pounds. The beef industry is located primarily in the central United States. The largest operations are in the Great Plains states, Texas, Kansas, Nebraska, and Colorado.

There has been a large shift in cattle production to the central United States as shown in Figure 3.7. Many areas have lost cattle production while Nebraska, Kansas, Oklahoma, and Texas have had great increases in cattle production.

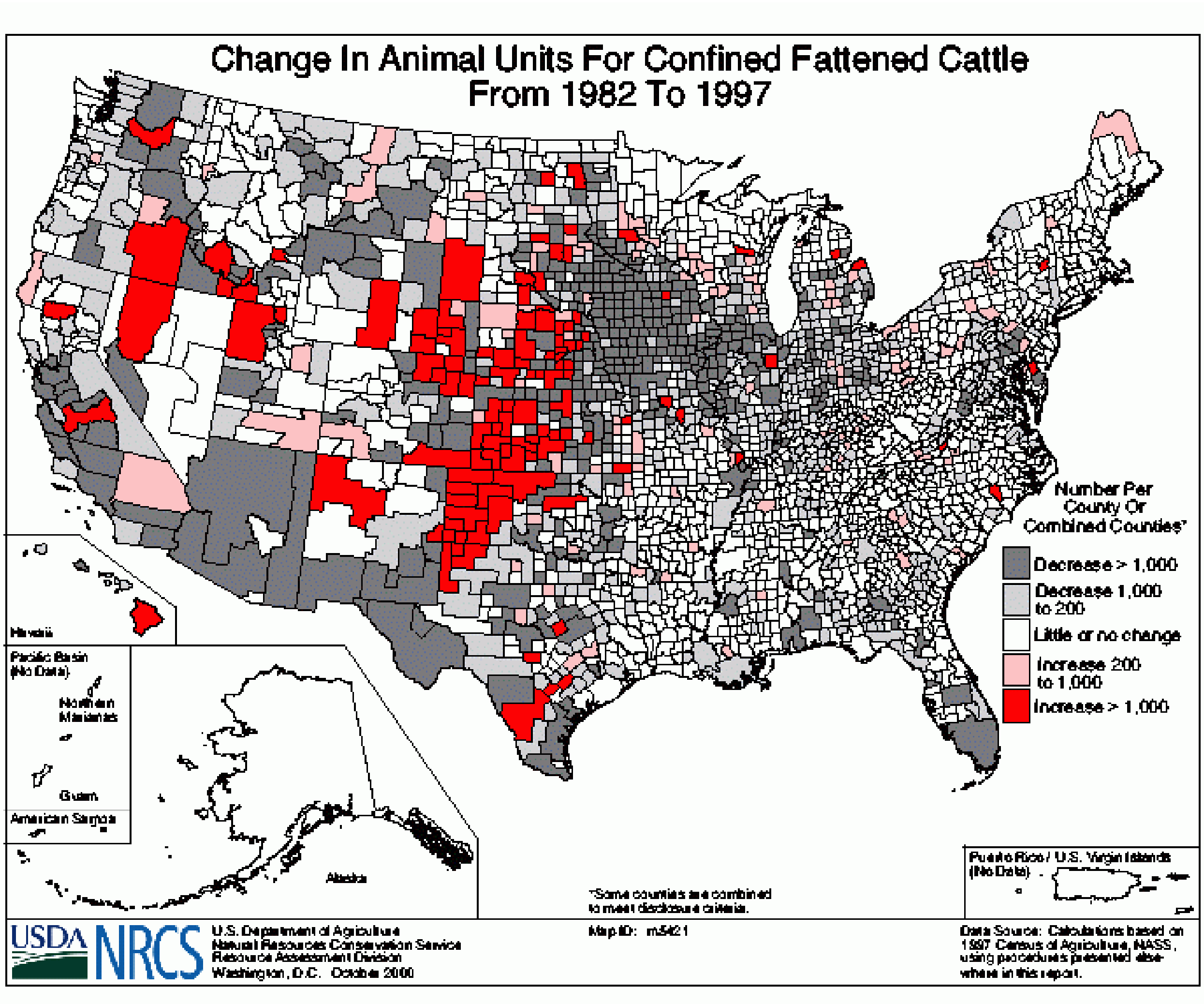

Figure 3.7. Change in cattle locations as of 1997 Census.

Figure 3.8 shows an aerial view of a large feedlot in Kansas. A waste lagoon is in the lower center of the picture. There is an area above the lagoon that appears to be the inflow area for the lagoon, but may also drain to unprotected streams. In large feedlots as shown in the figure, waste is generally scraped from the surface of the lot and piled nearby until it may be moved from the site for field application. A limited amount of treatment occurs in the piles due to self-heating of the material. Treatment by composting could be implemented relatively easily with the manure scraped from feedlots. The compost could then be sold as a value added product. The cost would be in the additional handling required to manage the composting process. Veal calf production is more likely to use a fully liquid manure system to handle wastes because the animals produce waste with higher water content and are held in confinement where water cleaning of the barns is practiced.

Photo courtesy of USDA NRCS.

Figure 3.8. Aerial view of a feedlot in Kansas with a lagoon.

Perhaps one of the most important facts for the purposes of this document is that a total of 806 million wet tons of manure were shed by beef cattle in 1997 (only 13% of this quantity was excreted within CAFOs, however). The quantity of manure produced by fattening beef cattle in CAFOs increased only 3% in the fifteen-year interval from 1982 to 1997. Beef feedlot wastes vary widely due to climate, diet, feedlot surface, animal density, and frequency of cleaning. Aged manure loses, on a dry weight basis, up to 60% of the nitrogen, 50% of the phosphorus, and 35% of the potassium (Mathers, 1972) to volatilization, runoff, or leaching.

3.1.3.2 Dairy

Dairy production is more evenly distributed due partially to the highly perishable nature of milk. Large dairy operations exist in California, New York, Wisconsin, Pennsylvania, Minnesota, Texas, Michigan, Washington, Idaho, Ohio, New Mexico, and Arizona, Texas, Idaho, New Mexico, and Arizona.

The distribution of dairy operations in the United States is shown in Figure 3.9. The highly perishable nature of milk suggests a reason for the more even distribution of dairies than beef feedlots.

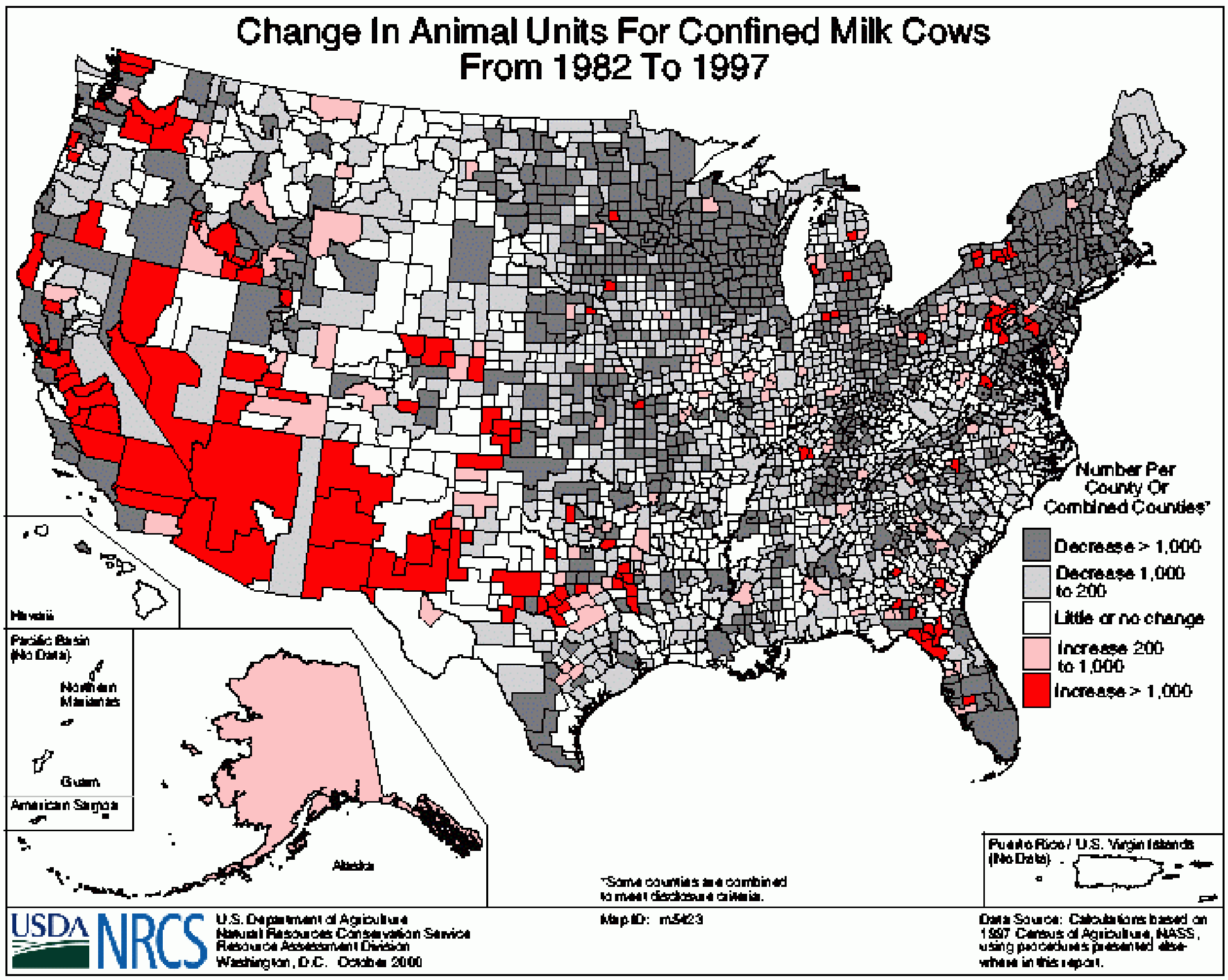

Figure 3.9. Change in distribution of dairy cattle in the United States.

Some dairies practice good control of waste both for nutrient management and for good environmental practice. Figure 3.10 shows a manure storage tank that gives the farmer good control over waste management. Tanks as shown may not be feasible for large dairies with large animal populations due to the volume of manure produced. Figure 3.11 shows a dairy farm with poor control of waste with consequent poor nutrient and environmental practices. This farm is losing valuable nutrients to runoff and possibly contaminating local streams with manure. Dairies may practice a variety of waste handling methods. Large dairies with large lot areas may handle wastes by scraping the lots and piling the waste until

Photo courtesy of USDA NRCS.

Figure 3.10. Dairy farm with manure storage tank

it may be field applied or further processed by composting. Milk house waste is frequently combined with the wash water and transferred to lagoons as a disposal mechanism separately from the feedlot waste. In this case there are two waste systems. Dairies with cows housed in barns and little or no outside activity usually have a combined waste system wherein the milk house waste, wash water and barn waste are combined in a mostly liquid system.

Dairy cattle produced 187 million wet tons of manure in 1997, representing an increase of 25% from the amount produced in 1982. Essentially this entire amount of fecal matter originated within CAFOs. Dairy manure as excreted contains on average TKN 164, phosphorus 29, and potassium 102 pounds/year/1000 pounds of animal mass (Lander, 1998). Water washed systems with lagoon storage may generate losses of 30-75% of the nitrogen (USDA 1992). The fecal matter produced within these operations was handled and disposed of under a variety of wet and dry handling systems and in some instances enclosed anaerobic digester systems have been employed so that methane gas production was optimized and then captured for conversion into electrical energy.

Photo courtesy of USDA NRCS.

Figure 3.11. Dairy farm with poor manure management and detrimental impact on the environment.

3.2 Manure Characteristics.

After the animals have defecated, the manure begins changing characteristics. Manure is a dynamic material, because it contains organic matter, nutrients, water, and microorganisms. Manure begins to lose N as NH_3 almost immediately. Between defecation and application of manure to soil, volatile N losses may be up to 90%. The N loss adversely affects the fertilizer value of the manure by reducing the N:P ratio. In most cases, conservation of the N is beneficial economically. Loss of N as NH_3 also raises an air pollution concern, as the N may be redeposited in watersheds where it becomes a pollutant. Esthetically, loss of N as NH_3 may create odor problems, leading to public disapproval of manure application, even though it is agronomically beneficial. Ammonia losses are minimized by direct injection or incorporation of manure into the soil surface. Up to 98% of N may be retained by injection. Maximum loss of N occurs when manure is applied by high velocity sprinkler systems. The sprayers maximize air exposure of the waste and consequently NH_3 loss. Phosphorus is not generally susceptible to volatility losses.

The nutrient value of animal waste varies according to animal species and waste handling systems. The nitrogen and phosphorus content of waste change greatly between excretion and field application. The urea and ammonia content of waste is especially susceptible to loss to atmosphere. This represents a potential economic loss as well as a transfer of a pollutant from one medium to another. Lagoon-based systems tend to accumulate phosphorus in the sludge layer on the bottom. Periodic removal of the supernatant disperses the N and P in the liquid phase. Eventually, the sludge layer will have to be removed to regain storage capacity. Due to the increased P content relative to the supernatant, the land area required for disposal will be greatly increased to prevent overloading with P. Examples of waste nutrient content are shown in Table 3.4.

Table 3.4. Nitrogen and Phosphorus Content of Animal Waste

Species	As excreted, lb/1000 lb/year		As applied, lb/1000 lb/year	
	N	P	N	P
Swine	54-228	18-168	17-20	17-22
Poultry, broiler	310-401	71-124	109	112, stockpile
Poultry, layer	264-315	99-113	238	94,pit
Turkey	204-270	84-120	102-132	82-102
Dairy	150-164	29-60	117	35
Beef	99-124	24-116	77	23-51

The wide range of nutrient content observed reinforces the need for the individual CAFO operator to have periodic manure analyses done. An annual analysis will provide adequate information for planning application for crops.

3.2.1 Physical Properties

The physical properties of manure produced by the main commercial animal species have some common and some individual characteristics. Poultry manure is drier upon excretion than manure produced by any other common species. The characteristics of manure of most interest for the purposes of this document include the moisture content, nutrient content, COD, and BOD representative of the different animal manures. Table 3.5 summarizes basic data on manure characteristics.

Table 3.5. Characteristics of animal manure based on 1000 pound live weight.

	Lbs/day	% water	Total solids	Volatile Solids	BOD5	N	P	K
Dairy	82	87	10.4	8.6	1.7	0.41	0.17	0.33
Beef	60	88	6.9	6.0	1.6	0.34	0.25	0.29
Swine Finisher	132	91	6.0	4.8	4.79	0.45	0.33	0.36
Layers	52.5	75	13.25	9.25	3.5	0.75	0.625	0.35
Broilers	70	75	18.0	12.5	1.15	1.2	0.615	0.45
Turkey	47	74	12	9.1	2.1	0.68	0.24	0.27
WWTP Influent	3.35	80 est.	2.7	1.2	1.7	0.25	0.17	na

The effects of excess nutrient release into the watershed may cause eutrophication of water bodies with consequent degradation of potential uses of the water. Harmful organisms may bloom in response to the nutrient input causing problems with fisheries and human health. And in the case of the Mississippi River ammonia inputs to the Gulf of Mexico have led to the development of extensive anoxic zones. Control of nutrient loss is important to management of animal wastes.

3.2.2 Nutrient Content and Form from Poultry

3.2.2.1 Layers, Broilers, and Turkeys

Poultry is made up of three sub-types: layers, broilers, and turkeys. Broilers and turkeys are fed to optimize growth and development, while layers are fed to maximize egg production. Manure produced by these groups reflects these differences as well as differences in housing practices.

Manure production and manure handling is similar in broilers and turkeys, resulting in similar nutrient concentrations. The floor is covered with moisture absorbing bedding and is ventilated. This airflow removes ammonia and other gases leaving a nitrogen depleted manure. Broiler manure as excreted has a nitrogen content of 401 lb/yr/1,000 lbs of animal mass (USDA, 1998); broiler house litter has a nitrogen content of 27 lb/yr/1,000 lbs of animal mass (USDA, 1992). Some of this decrease in nitrogen may be explained by solubilization as when bedding is washed off the floor rather than scraped as shown by the decrease in phosphorus and potassium from 117 and 157, respectively, to 113 and 111 lb/yr/1,000 lbs of animal mass. The much larger percent loss of nitrogen results from off-gassing of ammonia.

3.2.2.2 Layers

Layer manure production often includes no bedding, and it is handled as raw dried manure or water flushed manure. Water flushing manure results in dilution with a concurrent increase in volume. Raw manure contains 308, 114, and 120 lb/yr/1,000 lbs of animal mass of nitrogen, phosphorus, and potassium (USDA, 1998). Dry manure may lose up to 50% of the nitrogen content as volatile ammonia. Poultry manure dries rapidly and may be scraped off from flooring and stored dry in stacks or cakes. Dilution in lagoons and slurries may result in concentration reduction to as little as 10% of the raw manure value (USDA, 1992).

3.2.2.3 Nutrient Content and Form from Swine

Swine manure is typically collected in lagoons, pits, or both (Svoboda 1995). Nitrogen loss in the water fraction of the lagoons due to aeration may be as much as 76-84% of the original nitrogen content. Phosphorus and potassium losses to accumulation in sludge may be 78-92% of the phosphorus and 71-85% of the potassium (Jones and Sutton, 1994). The phosphorus and potassium lost from the aqueous stream are found in lagoon sludge.

Generally speaking, boars and larger swine produce manure with a higher nutrient content. Values reported here are for grower-finisher operations as these are more representative of the life-long manure production of the swine. Typical values are nitrogen, 166; phosphorus, 48; and potassium, 117 lb/yr/1,000 lbs of animal mass. Water-washed floors result in wet manure, which is often stored in lagoons.

3.2.2.4 Nutrient Content and Form from Cattle

3.2.2.4.1 Dairy

Average dairy manure as excreted contains TKN 164, phosphorus 29, and potassium 102 lb/yr/1,000 lbs of animal mass (Lander, 1998). These wastes are typically water-washed and stored in lagoons with concurrent loss of 30-75% of the nitrogen content (USDA, 1992).

3.2.2.4.2 <u>Beef</u>

Beef feedlot wastes vary widely due to climate, diet, feedlot surface, animal density, and frequency of cleaning. Feedlots are typically scraped and the resulting waste is stored on the ground. Aged manure loses, on a dry weight basis, up to 60% of the nitrogen, 50% of the phosphorus, and 35% of the potassium (Mathers, 1972) to volatilization, runoff, or leaching.

3.3 Manure Management Practices

3.3.1 Wet Manure Management

Liquid or slurry systems include wet barn washing, under-building or lagoon storage followed by spray application, injection, or gate and channel application onto the land. Liquid manure systems handle material with solids content below 10%. Gravity flow systems work well for movement of wastes from production to storage facilities, such as lagoons. Operations that require pumping to move wastes should have solids content of less than 4%. Liquid wastes are amenable to treatment in digesters. The digesters may be well engineered and controlled systems to increase efficiency, or enhanced lagoon storage to enable a lower intensity treatment, with longer treatment time. These systems are most amenable to recovery of fuel value from methane production. Swine and dairy operations commonly use wet manure management and are therefore potentially at risk from nitrogen percolation to groundwater and airborne stressor transport, especially if wastewater is sprayed. Liquid systems are described in more detail in the land application section.

3.3.2 Dry Manure Management

Solid manure systems include mechanical scraping of waste to clean out barns, pile storage and land application using a manure spreader, either truck-mounted or tractor-drawn powered spreaders. Dry systems include the manure plus any bedding material used. Typical bedding may be wheat straw, corn stover, corn cobs, sawdust, or any absorbent material. The bedding material absorbs water and changes the C:N ratio of the manure. The resultant material may then be suitable for composting with little need for adjusting carbon content.

Poultry and beef feedlot operations use dry manure management and so are more at risk from phosphorus application to land. Many CAFOs occupy only enough land for their day-to-day operations. The amount of manure produced in the CAFO may well exceed the capacity of the available land to absorb it. This is especially true when applications are based on phosphorus needs of crops rather than nitrogen. Offsite manure transfer may be a valuable way to expand the disposal area available. However, adequate record keeping and nutrient management is essential to avoid excess application to fields.

Typically, the smaller operations use familiar manure spreaders to distribute the manure in farm fields. Manure is loaded from the barn using a tractor-mounted scoop into a power driven spreader box or flail spreader. The spreader is driven to the field and the load distributed onto the land. The solid spreaders handle manure that is about 20 to 25% dry material, sometimes less. The material may be stacked with little or no liquid seepage. This type of manure is most easily treated by composting, should treatment be required before distribution. Incorporation of manure should be done as soon as possible after application to ensure N retention. Incorporation may not be done if the manure is applied to standing crops. The primary benefit of this system is relatively low cost for equipment. Evenness of distribution is not easily obtained. Timing of application is not generally done with nutrient management in mind. The small operator spreads manure when other activities are not pressing. Common times are: fall after harvest of corn and soybeans, winter, spring after planting is done, and summer after wheat is harvested. The largest risk would come from the winter application on frozen soil. Incorporation would not be feasible, and upon spring thaw and rainfall, runoff could produce significant losses of material to receiving water.